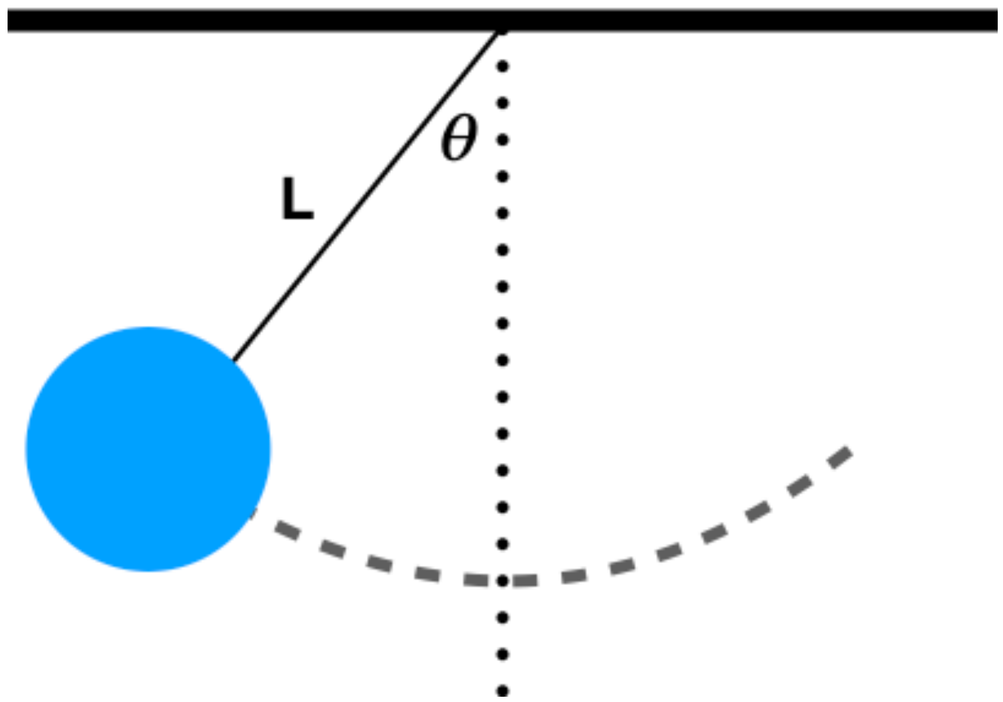
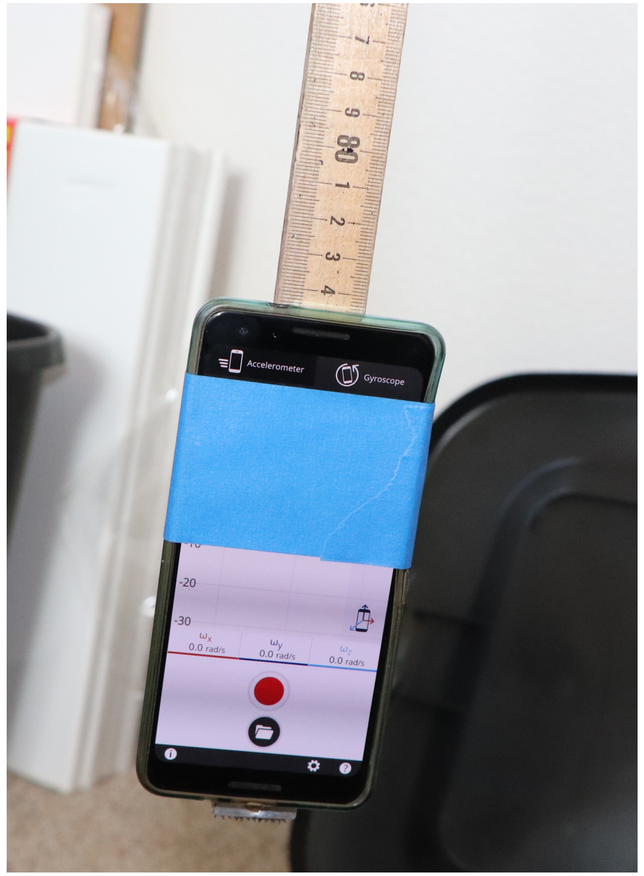
The Not-So-Simple Pendulum:

Theory, Experiment, and Computation in a DIY Remote Lab





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The Background

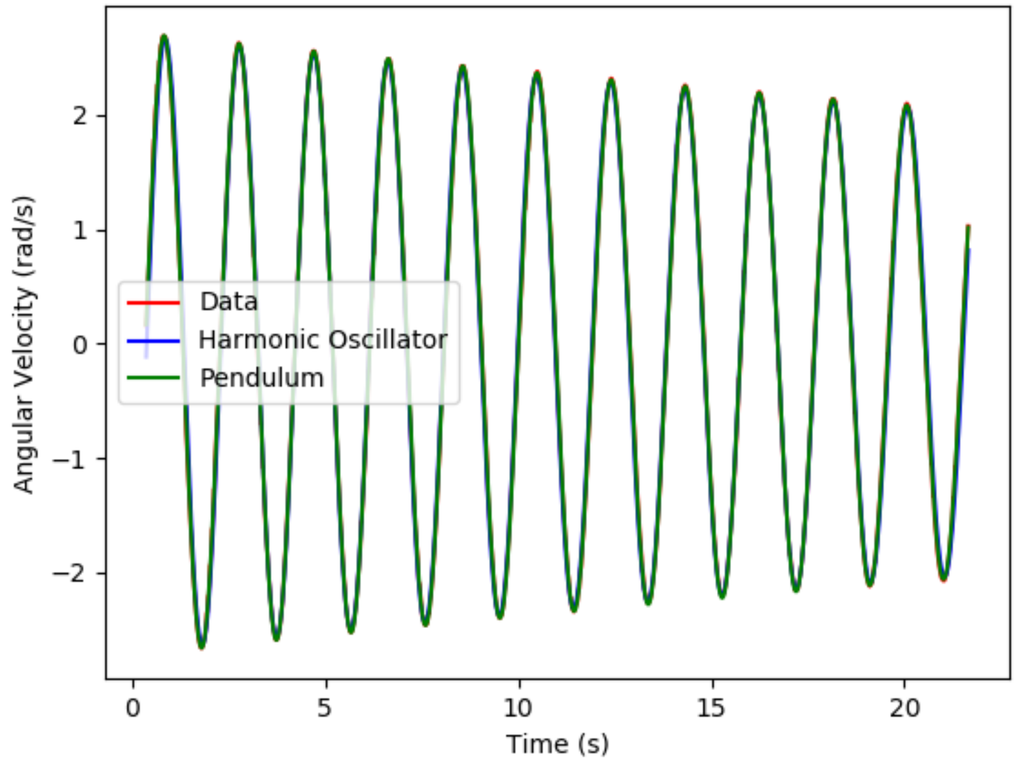
- Calc-based intro mechanics
- 24 students per lab section
- Students have used Python previously; code must be minimally altered
- Learning Objective: Use an experiment to distinguish between competing theoretical models of a physical system

“Prove that a damped pendulum is not a damped harmonic oscillator”

$$\frac{d^2\theta}{dt^2} = -\frac{g}{L}\sin\theta - 2\beta\frac{d\theta}{dt}$$

$$\frac{d^2\theta}{dt^2} = -\frac{g}{L}\theta - 2\beta\frac{d\theta}{dt}$$

Best Fit L = 86.1 cm



Best Fit L = 91.9 cm

Modeling

Python (Jupyter or Spyder)

jupyter NSSP_model_and_data (unsaved changes)

Logout

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Run Markdown

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This is a script for loading data from a file and fitting it to two models -- a damped harmonic oscillator and a damped pendulum.

Initial guess for model parameters -- modify these if your fits don't do very well

In [0]:
```
length_guess = 1.0 #in m
damping_guess = 0.2 #in 1/s
theta0_guess = 1.0 #in rad
w0_guess = 0.0 #in rad/s
```

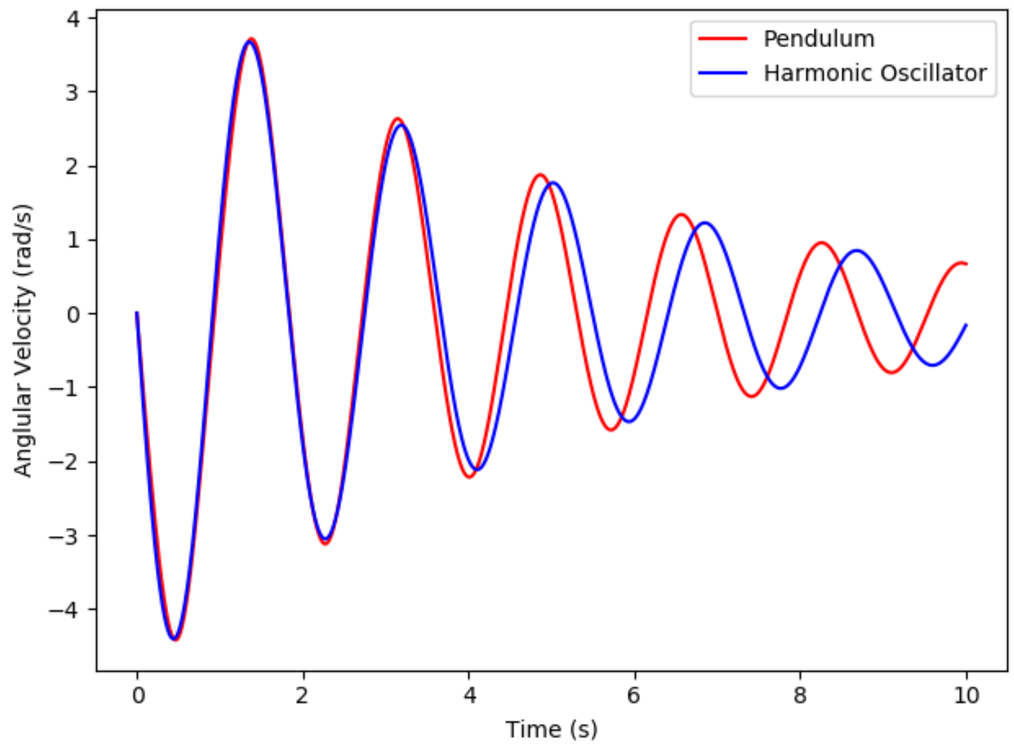
Enter the filename where you are stored your data (in .csv format) If you are running on Google CoLab you will also have to include code to this effect

file_id = '1v1cvYjjQziRtTbbnAnxcNLOZWlOSDML4'

!gdown https://drive.google.com/uc?id={file_id}

In [0]:
```
filename = 'gyroscope_x-y-z_SmallAngle_clipped.csv'
```

In [0]:
```
import numpy as np
import matplotlib.pyplot as plt
import scipy.optimize as spo
import scipy.integrate as spi
```



In Person

- Work in groups
- Uses 2 three-hour lab sessions
- Python set up on lab computers; no installation needed
- Major student issues:
  - Help with code
  - Formatting and selecting data
  - Understanding connections between models and data

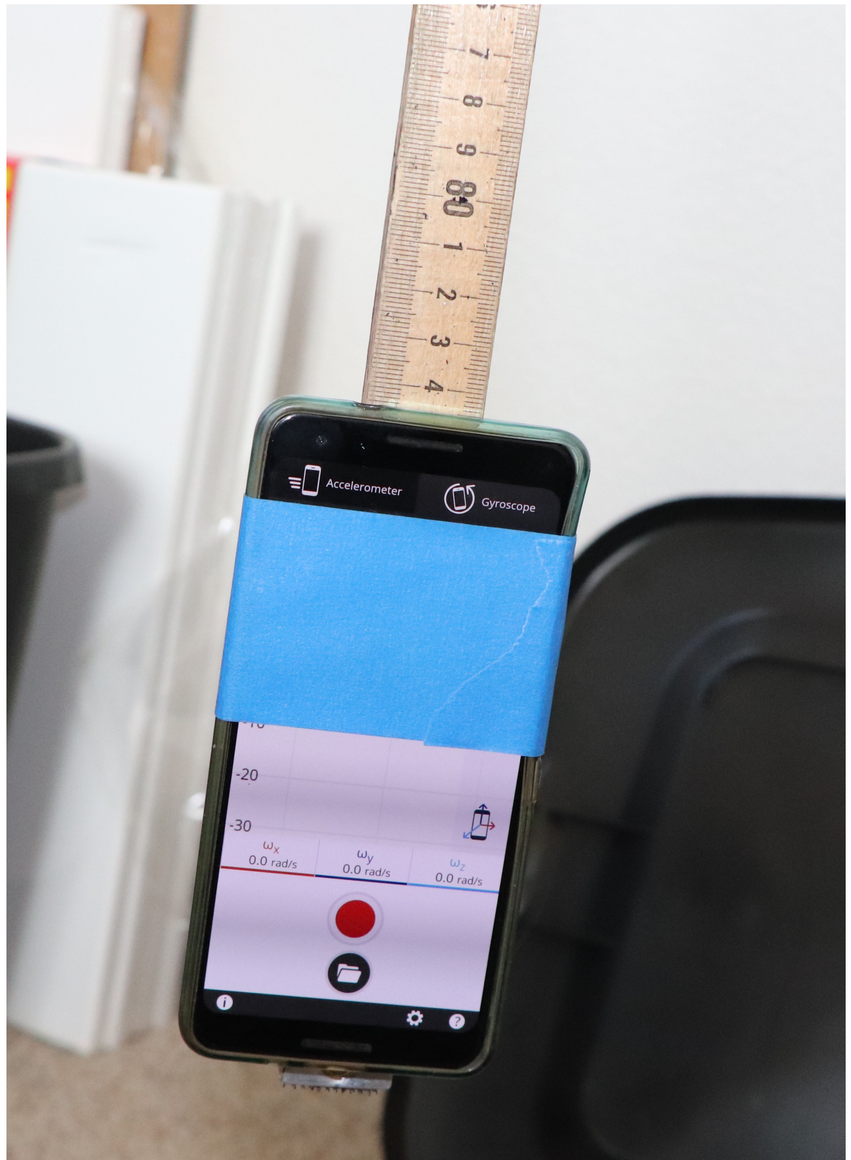
Moving Online

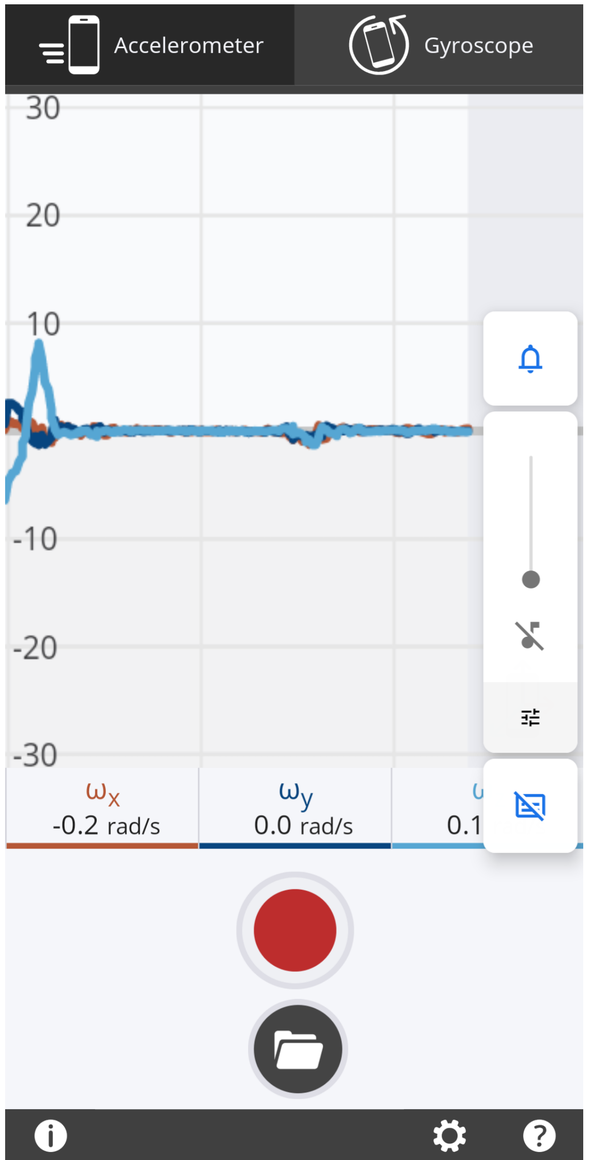
- Can’t physically work in groups
- Don’t have the Vernier/PASCO sensors
- Don’t have Python installed
- Don’t have general lab equipment

Solution: Phones, Google Sheets, and whatever you have at home

Taking Data


Super Value
CANVAS
16" x 20"


Accelerometer
Gyroscope


Accelerometer
Gyroscope
30
20
10
-10
-20
-30
ωx
-0.2 rad/s
ωy
0.0 rad/s

Modeling

Google Sheets

Data_Models_MedAngle

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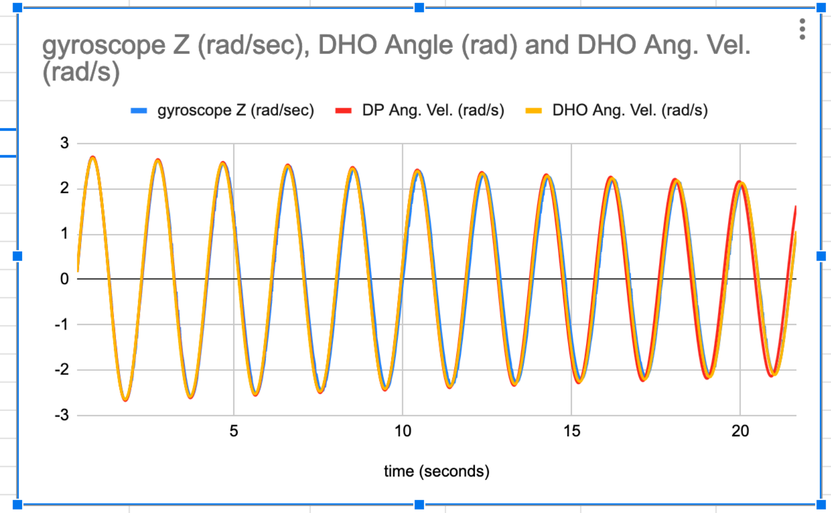
	A	B	C	D	E	F
1	time (seconds)	gyroscope Z (rad/sec)	DHO Angle (rad)	DHO Ang. Vel. (rad/s)	DP Angle (rad)	DP Ang. Vel. (rad/s)
2	0.357	0.16	-0.82	0.16	-0.82	0.16
3	0.374	0.28	-0.8147512579	0.3087495348	-0.8148449319	0.3032393026
4	0.39	0.41	-0.8075865305	0.44779546	-0.8078473765	0.4373472068
5	0.407	0.54	-0.7974855596	0.5941747594	-0.7980071337	0.5788378174
6	0.424	0.67	-0.7849283193	0.738661197	-0.7857853061	0.7189310315
7	0.441	0.81	-0.7699545531	0.8808097774	-0.7712114733	0.8572842816
8	0.457	0.94	-0.7537628014	1.011984481	-0.7554429628	0.9855319066
9	0.474	1.07	-0.7342405865	1.148365581	-0.7364112995	1.119509605
10	0.491	1.2	-0.7124610685	1.281148117	-0.7151495186	1.250692997
11	0.508	1.32	-0.6884923622	1.409923899	-0.691711519	1.378705855
12	0.524	1.44	-0.6640606633	1.526981184	-0.6677780446	1.49584215
13	0.541	1.68	-0.6360638242	1.646872889	-0.6402957861	1.616603443
14	0.558	1.79	-0.6061160331	1.76163477	-0.6108340947	1.733040671
15	0.575	1.79	-0.5743104805	1.870914858	-0.579473352	1.844749572
16	0.591	2	-0.5428178059	1.96829216	-0.5483524846	1.945054209
17	0.608	2.09	-0.5076957978	2.066000477	-0.5135631425	2.046431893
18	0.625	2.09	-0.4710217839	2.157294934	-0.4771510365	2.141888584
19	0.642	2.26	-0.4329095436	2.241896489	-0.4392235648	2.231027751
20	0.659	2.26	-0.393477247	2.31954686	-0.3998946782	2.313463915
21	0.675	2.33	-0.3553034155	2.385864469	-0.3617443761	2.38439388
22	0.692	2.47	-0.3136640911	2.449372026	-0.3200470027	2.452786673
23	0.709	2.47	-0.2710740437	2.505296906	-0.2773183573	2.513449726
24	0.726	2.58	-0.2276650594	2.553469664	-0.2336949188	2.566084619
25	0.742	2.62	-0.186203048	2.591375713	-0.1919698347	2.607817757
26	0.759	2.62	-0.1415931637	2.624110836	-0.1470192987	2.644149178
27	0.776	2.68	-0.09656463922	2.648736736	-0.101598997	2.671782453
28	0.793	2.69	-0.05125656655	2.665180746	-0.055859281	2.690571528
29	0.81	2.69	-0.005808843568	2.673395469	-0.009952200486	2.700416501
30	0.826	2.69	0.03696493358	2.673361071	0.0332672459	2.701215399

	H	I
1	Inital Angle (rad)	-0.82
2	DHO Length (m)	0.918
3	Pendulum Length (m)	0.85
4	g (m/s^2)	9.8
5	Damping (s^-1)	0.012



Did it work?

- Student feedback was largely positive; biggest complaint was being asked to swing their phones
- Completion was higher for this lab than any other post-COVID labs
- Google sheet issues were easy to trouble shoot remotely